U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Geologic map of the Yellowhorse Flat quadrangle, northern Mohave County, Arizona

by
George H. Billingsley[1]

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[1]U.S. Geological Survey, Flagstaff, Arizona

INTRODUCTION

The Yellowhorse Flat 7.5′ quadrangle is located in northern Mohave County, Arizona, bordering the Utah/Arizona state line. The nearest settlement is St. George, Utah, about 16 kilometers (10 mi) northwest (fig. 1). Elevations range from about 840 m (2,760 ft) at Dutchman Wash (northwest corner of quadrangle) to about 1,555 m (5,104 ft), at a triangulation point called Butte (east-central edge of quadrangle). Access to the quadrangle is by dirt road, locally referred to as the Sunshine Trail from St George, Utah (fig. 1). Several unimproved, 4-wheel drive dirt roads lead from the Sunshine Trail to various locations within the quadrangle.

The area is managed entirely by the U.S. Bureau of Land Management. The area is sparsely vegetated with sagebrush, cactus, greasewood bushes, and various desert shrubs.

PREVIOUS WORK

There are two previous geologic maps of this quadrangle area, a photogeologic map by Pomeroy (1959), and a partial map by Petersen (1983). Prior to this work, the area was included in Arizona state geologic maps at a scale of 1:500,000 (Wilson and others, 1969), and 1:1,000,000 (Reynolds, 1988). One geologic map borders this area, the Lizard Point 7.5′ quadrangle (Billingsley, 1990a). Geologic maps in preparation by the author bordering this quadrangle include, the Hole-N-Wall Canyon (south), and the Rock Canyon 7.5′ quadrangle (east). The Hurricane 15′ quadrangle (north) is in preparation by W.K. Hamblin, Brigham Young University, Provo, Utah.

MAPPING METHODS

Geologic mapping of this quadrangle began with a general knowledge of Colorado Plateau geology based on literature and previous mapping experience on the Colorado Plateau. First, reconnaissance of the map area was conducted to gain a general sense of the geological formations and structures. Second, a photogeologic interpretation of the area was done. Third, extended field investigation covered at least 85% of the map area to check geologic photo interpretations. Fourth, additional photogeologic study was made to provide consistency in map units and overall geologic map sense. Finally, field investigation of local problem areas was conducted to insure accuracy and consistency of map units. Many of the Quaternary units are identified by geomorphological characteristics expressed on photos. The Quaternary map units are important for environmental, land, and range management planning by federal, state, and private concerns.

GEOLOGIC SETTING

The quadrangle lies within two sub-provinces of the Colorado Plateau, the Shivwits Plateau and the St. George Basin. The physiographic boundary between the higher Shivwits Plateau and the lower St. George Basin follows the Dutchman Draw fault in the west half of the quadrangle to Joe Blake Hill, then turns southeast along the east rim of East Mesa to Butte benchmark, and finally heads straight east to the edge of the quadrangle (fig. 2). The Shivwits Plateau is characterized by relatively flat-lying bedrock with a regional dip about 3°to 5° northeast. Bedrock strata of the St. George Basin are gently folded into plunging anticlines and synclines with a general north-south trend. Fault and fold structures of this quadrangle are dissected by

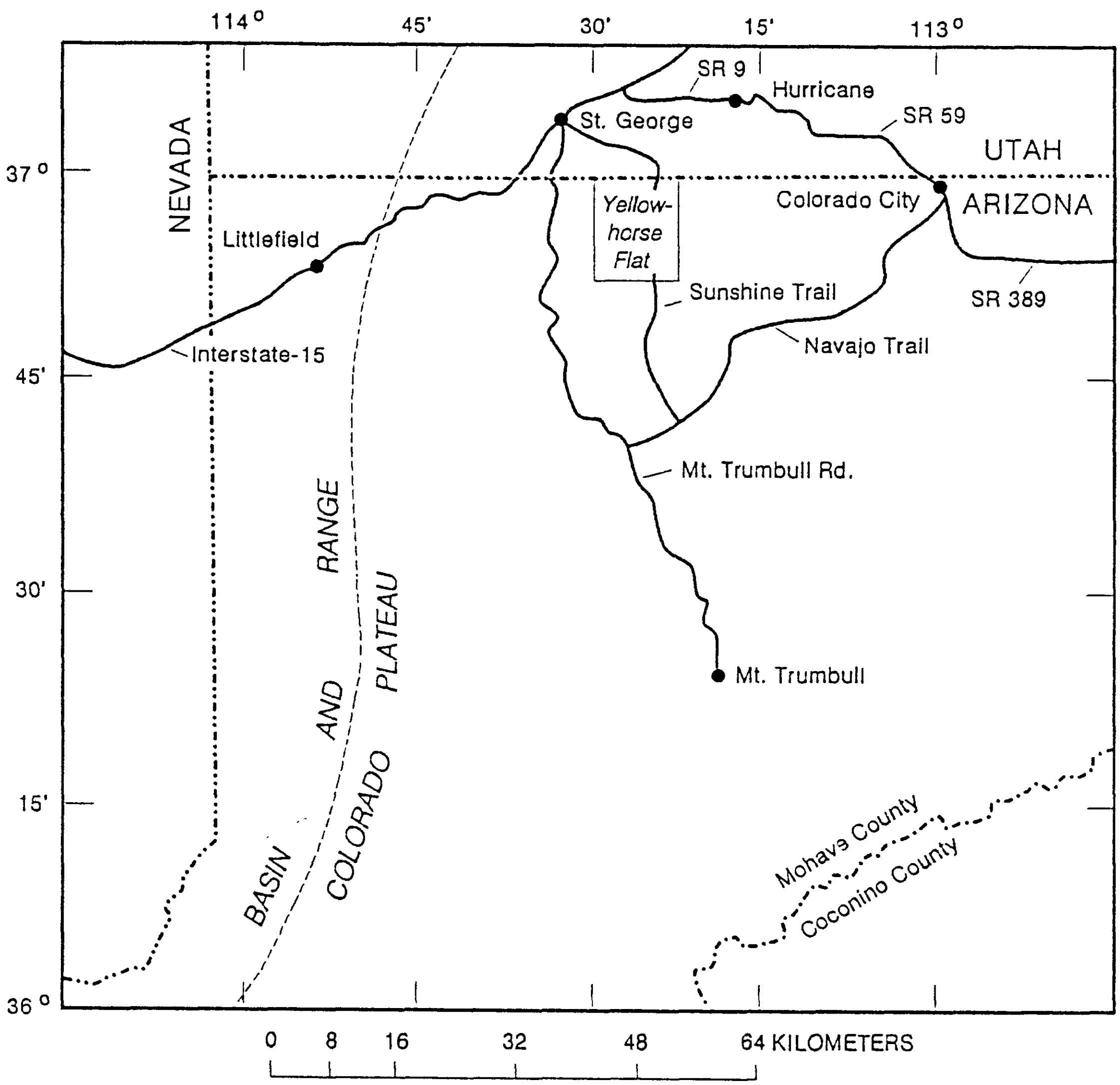


Figure 1. Index map of northern Mohave County, northwestern Arizona, showing the Yellowhorse Flat 7.5′ quadrangle mapped in this report.

Dutchman Draw drainage and its tributaries where about 580 m (1,900 ft) of Permian and Triassic strata are exposed.

Cenozoic deposits are widely distributed and characterized as fluvial or landslide deposits based on topographical landform development and their morphological relations to structures and erosional surfaces. The surficial units locally intertongue and share arbitrary map boundaries. Other Cenozoic rocks are igneous basalt dikes and flows and pyroclastic deposits scattered throughout the quadrangle.

STRATIGRAPHY

The sedimentary bedrock strata include, in ascending order, the Toroweap and Kaibab Formations (Lower Permian), and the Moenkopi and Chinle Formations (Upper? Middle? and Lower Triassic). The Woods Ranch Member of the Toroweap Formation, crops out in Dutchman Draw drainage, west-central part of the quadrangle. The youngest pre-Cenozoic unit, the Petrified Forest Member of the Chinle Formation, crops out in the northwest and northeast corners of the quadrangle. About one-third of the surface bedrock exposed in the quadrangle is gray cherty limestone and gray to white siltstone and gypsum of the Kaibab Formation. The other two-thirds of exposed bedrock is mostly red siltstone and sandstone and gray gypsum and dolomite of the Moenkopi Formation.

The West Mesa and East Mesa basalt flows (informal stratigraphic units), are assumed to be Pleistocene age. The West and East flows occupy an eroded surface 430 m (1,400 ft) below late Pliocene basalt flows of nearby Seegmiller Mountain (2.35±0.31 and 2.44±0.51 Ma; Reynolds and others, 1986). There are no faults of any consequence between Seegmiller Mountain and the West and East Mesa flows, a distance of about 5 km (3 mi) (Billingsley, 1990b). Thus, the West and East basalt flows were deposited long after erosion of the Seegmiller Mountain region. Both West and East flows are similar in lithology and elevation but are separated by a valley about 2 km wide (fig. 2).

The West Mesa basalt occupies a Quaternary paleovalley that had a northerly gradient of about 18 m/kilometer (60 ft/mi). The basalt originates from two or more vent or dike sources about 3 to 5 km (2 to 3 mi) south of this quadrangle (Hole-N-Wall Canyon quadrangle). The West Mesa basalt overlies Quaternary alluvium, sandstone, limestone, and gypsum of the Timpoweap Member and lower red member of the Moenkopi Formation, and Harrisburg Member of the Kaibab Formation. The West Mesa paleovalley is probably an ancestral drainage of today's Dutchman Draw. Today, Dutchman Draw has eroded about 100 to 150 m (350 to 500 ft) deeper than the West Mesa basalt and parallels the west margins of West Mesa.

The East Mesa basalt occupies another Quaternary paleovalley paralleling the West Mesa paleovalley (fig. 2). The gradient of East Mesa paleovalley is about 15 m/kilometer (50 ft/mile) north. The basalt flow originated from vents now exposed as dikes, necks, and cinder cones on East Mesa and the eroded flanks of the mesa. The basalt flowed out onto a surface of some local alluvial gravel but mostly onto bedrock strata of the Shnabkaib, middle red, and Virgin Limestone Members of the Moenkopi Formation.

The north end of the East Mesa basalt is offset by the Dutchman Draw fault at Joe Blake Hill (fig. 2). Displacement of the basalt and underlying strata are about equal, 100 m (320 ft) down to the northwest. Erosion along

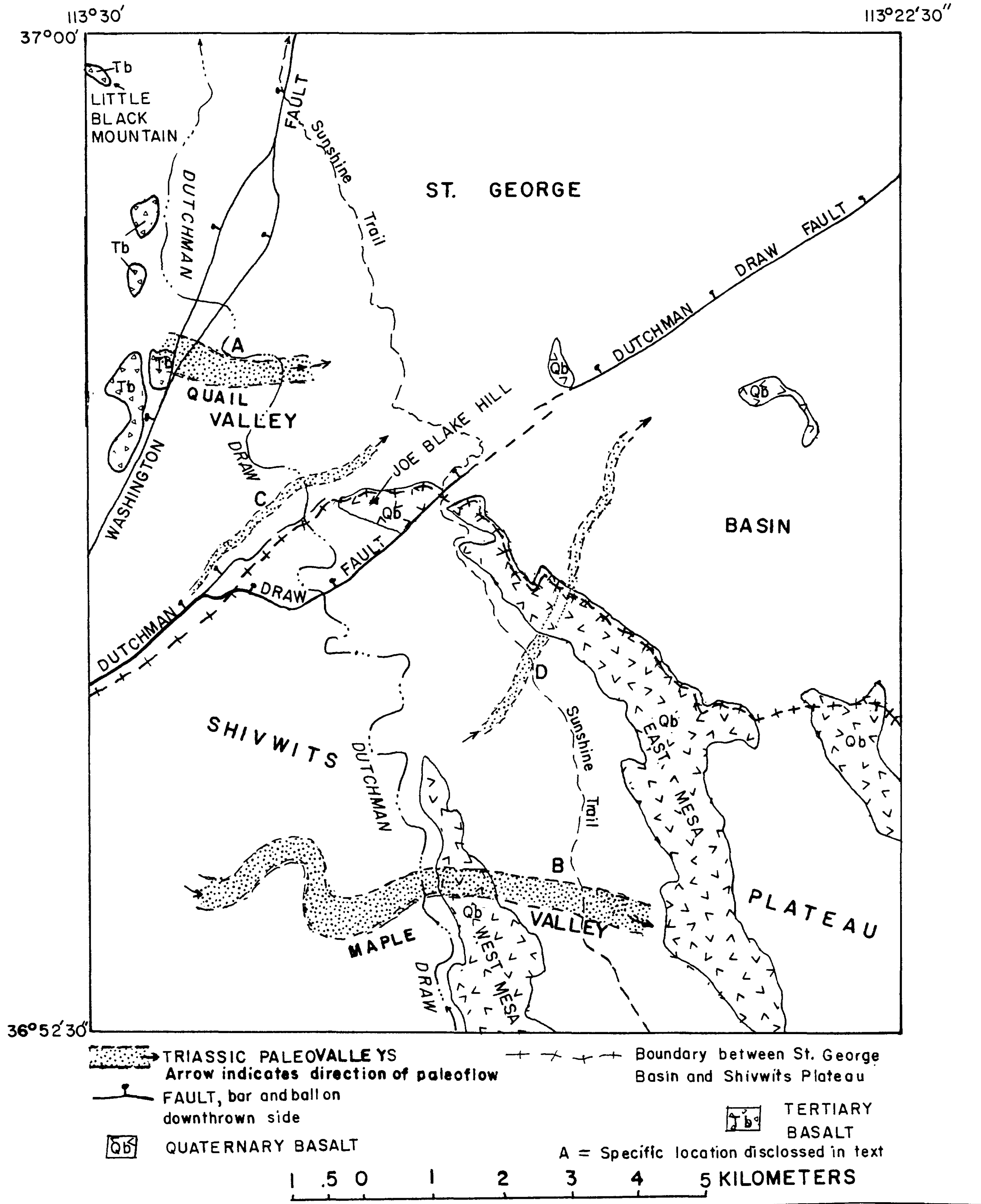


Figure 2. Selected geographic and geologic features of the Yellowhorse Flat 7.5′ quadrangle, northwestern Arizona.

the flanks of East Mesa has removed an average of about 170 m (550 ft) of Moenkopi and Kaibab strata since the basalt flow occurred. Assuming an age of about 1.0 Ma years, and the surrounding area was nearly level with the basalt, an estimated rate of downcutting is about 1.5 m (5.0 ft)/10,000 years.

The basalt flows capping Little Black Mountain in the northwest corner of the quadrangle overlie strata of the Chinle Formation (fig. 2). Their source area and ages are unknown but assumed to be Pliocene age. The Little Black Mountain basalt and outcrops along Dutchman Draw are on the downthrown side of the Washington fault. A petrographic examination may link the two basalt capped mountains together in future studies.

A correlation of Little Black Mountain basalt to Seegmiller Mountain basalt is postulated here because of a similar rock type in hand specimen. Little Black Rock Mountain is about 18 km (11 mi) north of Seegmiller Mountain. The basalt at Seegmiller Mountain generally overlies bedrock strata of the Shnabkaib Member of the Moenkopi Formation (Billingsley 1990b). The Seegmiller basalt flowed north down a gentle paleovalley slope and across strata up-dip to the Petrified Forest Member of the Chinle Formation. The regional dip is northeast and east about 3 to 5 degrees, enough to allow the Chinle strata to be lower at the north end of the paleovalley in 18 km. The Washington and Dutchman Draw faults and other smaller faults offset the basalts and underlying strata about 610 m (2,000 ft), dropping them down to the northwest during the past 2.4 million years, the age of the Seegmiller basalt. The faulting averages about 2.5 m (8.3 ft) displacement per 10,000 years.

The Quaternary age assigned to the alluvial deposits is based on field relationships of alluvial deposits with Quaternary basalt flows of East and West Mesa (this quadrangle) and Pliocene basalts elsewhere (Billingsley, 1991). Details of the stratigraphic sequence are given in the description of maps units.

STRUCTURAL GEOLOGY

The Washington and Dutchman Draw are the main faults of this quadrangle and both have a northeast strike (fig. 2). The Washington fault displaces strata down to the northwest about 500 m (1,650 ft) with strata dipping gently east or northeast on the both sides of the fault. The fault plane is mostly covered and appears to be nearly vertical fault in this quadrangle (Petersen, 1983). The Washington fault is a high-angle reverse fault southwest of this quadrangle at about the junction of the Dutchman Draw and Washington faults (Billingsley, 1990a).

The Dutchman Draw fault, named from Dutchman Draw in this quadrangle, intersects the Washington fault about 0.8 km (0.50 mi) west of this quadrangle. The Dutchman Draw fault has an average normal displacement of about 115 m (375 ft) at the west edge of the quadrangle. The fault splits into two segments in the central part of the quadrangle. About a kilometer of the fault trace is mostly covered by landslide and other Quaternary deposits northeast of Joe Blake Hill. The trace of the Dutchman Draw fault continues slightly enechelon and on strike to the northeast quarter of the quadrangle (fig. 2). A synclinal fold parallels the downthrown side of the fault.

Elsewhere, a few small normal faults are located south of the Dutchman Draw fault. Several small plunging synclines and anticlines are common north of the Dutchman Draw fault, a characteristic of the St. George Basin.

Holocene movement has occurred along parts of the Washington and Dutchman Draw faults. Fault scarps in talus and alluvial fans are common, but the scarps are not sharply defined in the field because of recent mass-wasting shedding soft and loose debris over the scarps. Therefore, the faults are shown dotted in the alluvial units of the map where they mark map-unit contacts, and solid where faulting appears recent. The Washington and Dutchman Draw faults began their development after emplacement of the late Pliocene basalt flows because the basalts are offset the same amount as underlying sedimentary strata (Billingsley, 1991).

Short plunging anticlines and synclines are present in the northwest quarter of the quadrangle and generally have a north or northeast trend. These folds, like others found elsewhere on the Colorado Plateau, are probably related to early Laramide compressional stresses (Huntoon, 1989). Warped and bent strata, too small to show at map scale, are the result of solution of gypsum and are commonly associated with collapse structures or drainage erosion.

Collapse Structures

Circular collapse structures and irregular sinkholes are mostly due to solution of gypsum and gypsiferous siltstone. However, some circular, bowl-shaped depression surrounded by inward-dipping strata may be collapse-formed breccia pipes originating in the deeply buried Mississippian Redwall Limestone (Wenrich and Huntoon, 1989; Wenrich and Sutphin, 1989). Such features in this quadrangle are marked by a dot and the letter "C" to denote possible deep-seated breccia pipes. They cannot with certainty be distinguished by surface forms from shallow collapse structures caused by removal of gypsum. Moreover, some deep-seated breccia pipes are known to be overlain by gypsum-collapse features (Wenrich and others, 1986). Those collapse features in the lower red member of the Moenkopi (northern half of quadrangle), may be shallow gypsum collapse features. They are not be confused with deep-seated breccia pipes because they are small and exhibit locally bleached alteration. The deep-seated breccia pipes are a possible host for potential economical deposits of copper and uranium minerals (Wenrich, 1985).

Shallow sinkholes and karst caves are associated with the solution of gypsum in the Harrisburg Member of the Kaibab Formation, and the Virgin Limestone Member of the Moenkopi Formation. The sinkholes are young features of Holocene and probable Pleistocene age. Hundreds of sinkhole depressions breached by drainages on the Shivwits Plateau surface are not mapped. Only sinkholes that are an enclosed depression are shown with a triangle and "s" symbol. Several drainages originate at sinkhole depressions in the southwest quarter of the quadrangle.

DESCRIPTION OF MAP UNITS

Surficial deposits

Qaf **Artificial fill (Holocene)**--Stock tank and drainage diversion material quarried from surficial and bedrock deposits

Qs **Stream-channel alluvium (Holocene)**--Unconsolidated and poorly sorted, interlensing silt, sand, and pebble to boulder gravel. Intertongues with alluvial fan (Qa_1 and Qa_2), terrace-gravel (Qg_1 and Qg_2), valley-fill (Qv), and talus (Qt) deposits. Stream channels are subject to high-energy flows and flash floods and support little or no vegetation. Contacts approximate. Estimated thickness 1 to 5 m (3 to 15 ft)

Qd **Dune sand (Holocene)**--Light red and tan, eolian quartz sand, fine-grained, some red staining on quartz grains. Includes some gray chert grains. Locally derived from Fort Pearce Wash just off northeast edge of quadrangle. Forms small climbing dunes or sandsheets. Supports grassy vegetation. Thickness about 3 m (10 ft)

Qc **Colluvial deposits (Holocene)**--Chiefly silt and fine-grained sand. Includes lesser amounts of angular pebble to cobble gravel; locally consolidated. Accumulates in enclosed basins created by landslide debris depressions. Subject to temporary ponding. Sparse or no vegetation. Estimated thickness 3 to 9 m (10 to 30 ft)

Qg_1 **Young terrace-gravel deposits (Holocene)**--Unconsolidated light-brown, pebble to boulder gravel composed about equally of well-rounded limestone and sandstone, angular and subrounded chert; includes interstratified lenses of silt and sand. Locally includes well-rounded to rounded basalt clasts. Includes reworked materials from alluvial fans (Qa_1, Qa_2, and Qa_3), terrace-gravels (Qg_2 and Qg_3), and talus (Qt) deposits. Forms bench about 1 to 3 m (3 to 10 ft) above modern stream beds. Thickness averages about 1 to 3 m (3 to 10 ft)

Qa_1 **Young alluvial fan deposits (Holocene)**--Unconsolidated silt and sand; contains lenses of coarse gravel composed of subangular to rounded pebbles to cobbles of limestone, chert, sandstone, and basalt clasts; partly cemented by gypsum and calcite. Intertongues with stream-channel (Qs), valley-fill (Qv), and young terrace-gravel (Qg_1); overlaps and partly includes reworked materials from low and intermediate terrace-gravels (Qg_1 and Qg_2) and older alluvial fans (Qa_2 and Qa_3) deposits near their downslope ends. Alluvial fan subject to erosion by sheet wash and flash floods. Supports sparse vegetation of sagebrush, greasewood shrubs, cactus, and grass. Thickness as much as 6 m (20 ft)

Qv **Valley-fill deposits (Holocene and Pleistocene?)**--Partly consolidated silt, sand, and interbedded lenses of pebble to small-boulder gravel. Intertongues with talus (Qt), low terrace-gravel (Qg_1), and alluvial fan (Qa_1 and Qa_2) deposits. Valleys subject to sheetwash flooding and temporary ponding; cut by arroyos in some larger valleys. Supports thick vegetation of greasewood shrubs, sagebrush, grass, and cactus. Thickness as much as 9 m (30 ft)

Qg_2 **Low terrace-gravel deposits (Holocene and Pleistocene?)**--Similar to young terrace-gravel deposits (Qg_1), partly consolidated; on benches and abandoned stream channels about 4 to 9 m (12 to 30 ft) above modern stream beds. Intertongues with and locally overlain by talus (Qt) deposits. Thickness about 2 to 7 m (5 to 23 ft)

Qa_2 **Intermediate alluvial fan deposits (Holocene and Pleistocene)**--Similar to young alluvial fan deposits (Qa_1), partly cemented by calcite and gypsum; generally lies above but often overlapped by young alluvial fan (Qa_1) and talus (Qt) deposits. Intertongues with or inset against alluvial fan (Qa_3) and talus (Qt) deposits. Locally includes basalt clasts. Fans are moderately vegetated by sagebrush, cactus, greasewood shrubs, and some grass. Thickness about 3 to 12 m (6 to 40 ft)

Qt **Talus deposits (Holocene and Pleistocene)**--Unsorted debris consisting of breccia and large angular blocks of local bedrock up to 1 m diameter. Includes silt, sand and gravel, partly cemented by calcite and gypsum. Intertongues with alluvial fans (Qa_1, Qa_2, and Qa_3), valley-fill (Qv), and terrace-gravel (Qg_1 and Qg_2) deposits. Supports sparse to moderate vegetation of greasewood shrubs, sagebrush, cactus, and grass. Only relatively extensive deposits shown. Thickness as much as 9 m (30 ft)

Ql **Landslide deposits (Holocene and Pleistocene)**--Unconsolidated masses of unsorted rock debris. Includes blocks of detached segments of strata that have rotated backward and slid downslope as loose, incoherent mass of broken rock and deformed strata, often partly surrounded by talus. Occurs principally below edges of basalt flows of East Mesa, the east flank of Butte benchmark (east edge of map), and at Little Black Mountain (northwest corner of map); includes basalt flows and strata of Chinle and Moenkopi Formations that have slid down over weak shale and gypsum units of the Chinle and Moenkopi. Supports sparse vegetation of greasewood shrubs, sagebrush, cactus, and grass. Unstable when wet. Thickness probably as much as 43 m (140 ft)

Qg_3 **Low intermediate terrace-gravel deposits (Pleistocene)**--Similar to young and low terrace-gravel deposits (Qg_1 and Qg_2), but 6 to 11 m (20 to 35 ft) higher than Qg_2 and about 8 to 18 m (25 to 60 ft) above modern drainages. Composed of well-rounded limestone, sandstone, and chert clasts in sandy gravel matrix. Locally includes abundant, well-rounded clasts of basalt in north-central part of quadrangle. Partly consolidated by calcite and gypsum cement. Thickness as much as 6 m (20 ft)

Qa_3 **Older alluvial fan deposits (Pleistocene)**--Similar to younger and intermediate alluvial-fan deposits (Qa_1 and Qa_2). Intertongues with talus (Qt) deposits. Often adjacent to or overlapped by younger alluvial fans (Qa_1 and Qa_2), and talus (Qt) deposits. Basalt clasts abundant. Thickness about 3 to 8 m (10 to 25 ft)

Qg_4 **High intermediate terrace-gravel deposits (Pleistocene)**--Similar to younger terrace-gravel (Qg_1, Qg_2, Qg_3) deposits and 3 to 6 m (10 to 20 ft) higher than Qg_3 deposits and about 14 to 23 m (45 to 75 ft) above modern drainages. Composed of well-rounded basalt, limestone, sandstone and chert clasts in fine-grained sandy matrix. Partly consolidated by calcite and clay cement. Thickness as much as 6 m (20 ft)

Qg_5 **High terrace-gravel deposits (Pleistocene)**--Similar to younger terrace-gravel deposits (Qa_1, Qg_2, Qg_3, and Qg_4), but 2 to 5 m (5 to 15 ft) higher than Qg_4 deposits and about 26 m (85 ft) above modern drainages. Composed of well-rounded chert, basalt and limestone clasts in sandy matrix. Partly consolidated by calcite and clay cement. Thickness as much as 5 m (15 ft)

Igneous rocks

Qi **Basalt dikes and plugs (Pleistocene)**--Dark-gray, finely crystalline, aphanitic basalt, weathers into crumbly small fragments due to abundant cooling joints. Includes black pyroxene. Assumed to be Pleistocene age. Represents shallow vent system for basalt flows of East and West Mesas and two isolated, unnamed buttes north of East Mesa

Qbc **Basalt cinder and scoria deposits (Pleistocene)**--Red-brown and black clasts of vesicular, angular, basalt; contains dark-gray glass fragments; unconsolidated. Probably vent deposits. Forms slope with internal layering dipping away from vent area. Thickness about 30 m (100 ft)

Qb **Younger basalt flows (Pleistocene)**--Dark-gray, massive basalt; finely crystalline, aphanitic groundmass; some large columnar joints at base of some flows, but not common. Surfaces are locally covered by cinder material on East and West Mesa flows. Flows on two unnamed buttes north of East Mesa are assumed to be Pleistocene age as described in Qi above because of similar lithology and elevation (fig. 2). Thickness, East and West Mesas, about 9 to 55 m (30 to 180 ft). Less than 15 m (50 ft) thick on unnamed buttes north of East Mesa

Tb **Older basalt flow (Pliocene)**--Dark massive basalt; finely crystalline, aphanitic groundmass, and sparse olivine phenocrysts. Surface is blocky and partly covered with gypsiferous siltstone. Includes basalt flow at Little Black Mountain and along Dutchman Draw, considered here to be northern extension of Pliocene basalt flow of Seegmiller Mountain (2.4 Ma; Reynolds and others, 1986). Consists of one flow averaging about 9 m (30 ft) thick.

Sedimentary Rocks

Chinle Formation (Upper Triassic)--Includes, in descending order, Petrified Forest and Shinarump Members as used by Stewart and others (1972)

ℝcp **Petrified Forest Member**--White, blue-gray, green-gray, pale-red, purple-red mudstone, siltstone, and some sandstone. Contains bentonitic clays derived from volcanic ash. Petrified wood fragments common. Only lower part is present, upper part is eroded away. Commonly covered by landslide, talus or alluvium. Gradational contact with underlying cliff-forming Shinarump Member. Forms slope. Estimated thickness about 60 m (200 ft)

ℝcs **Shinarump Member**--Orange-brown to tan, cobble to coarse-grained, thin-bedded and massive conglomerate and sandstone. Weathers dark-brown. Includes stream-channel deposits largely composed of well-rounded chert or quartzite clasts and gravel, about 30% of clasts are black, well-rounded chert? or schist? Contains fossil chert wood fragments and petrified logs. Fills erosion channels cut into upper red member of Moenkopi Formation as much as 30 m (100 ft). Unconformable contact with Moenkopi Formation. Forms cliff. Variable thickness 25 to 55 m (80 to 180 ft)

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order, upper red member, Shnabkaib Member, middle red member, Virgin Limestone Member, lower red member, and Timpoweap Member as used by Stewart and others (1972). The Middle-Lower Triassic boundary probably lies in the upper red member

Ŧmu **Upper red member**--Heterogeneous sequence of red sandstone, siltstone, mudstone, conglomerate, and minor gray gypsum. Includes thin-bedded cliff of sandstone in upper part. Gradational contact with Shnabkaib Member placed arbitrarily at highest thick white siltstone and dolomite bed of Shnabkaib. Forms slope and ledge sequence about 67 m (220 ft) thick

Ŧms **Shnabkaib Member**--Interbedded, white, laminated, aphanitic dolomite and silty gypsum; includes red, thin-bedded mudstone, siltstone and sandstone in lower part. Gradational contact with middle red member arbitrarily placed at base of lowest bed of light-gray dolomitic limestone or siltstone of Shnabkaib Member. Forms steep slope with ledges. Thickness as much as 153 m (500 ft)

Ŧmm **Middle red member**--Interbedded, red-brown, thin-bedded, laminated siltstone and sandstone, white and gray gypsum, minor white platy dolomite, green siltstone, and gray-green gypsiferous mudstone. Gradational contact with Virgin Limestone Member placed at top of highest gray limestone bed of Virgin Limestone. Forms slope. Thickness about 45 to 60 m (150 to 200 ft)

Ŧmv **Virgin Limestone Member**--Consists of three, sometimes four, light gray, ledge forming, limestone beds 2 to 6 m (5 to 20 ft) thick, separated by white, pale-yellow, and gray, slope-forming, thin-bedded, gypsiferous siltstone. Includes thin beds of brown, red, and green siltstone, gray limestone, and brown platy calcarenite in slope-forming units. Lowest limestone bed contains abundant star-shaped crinoid plates and poorly preserved Composita brachiopods in top part. Contact with lower red member is sharp erosional unconformity, less than 1 m (2 ft) of relief at base of lowest gray Virgin Limestone bed. Forms small cliffs in slope. Thickness about 24 to 40 m (80 to 130 ft)

Ŧml **Lower red member**--Interbedded red, thin-bedded, sandy siltstone, gray, white, and pale-yellow laminated gypsum, and minor sandstone. Lower beds contain reworked gypsum and siltstone of Harrisburg Member of Kaibab Formation. Gradational contact with Timpoweap Member arbitrarily placed at lithologic change downward from red siltstone and gypsum to gray conglomerate or brown, coarse-grained sandstone. Forms slope. Thickness ranges from about 9 to 30 m (30 to 100 ft) thick, locally thickens to as much as 60 m (200 ft) in Triassic paleovalleys eroded into Kaibab Formation

Ꞅmt **Timpoweap Member**--Gray conglomerate, consisting of subangular to rounded pebbles and cobbles of gray and dark gray limestone, white and brown chert, and minor rounded quartzite. Chert and gray limestone is derived from Kaibab Formation. Dark gray limestone and quartzite may be from older Paleozoic rocks from source west of quadrangle. Mostly clast supported, includes matrix of gray to brown, coarse-grained quartz sandstone, gravel, and minor siltstone. Forms cliff. Fills Triassic paleovalleys eroded into Kaibab Formation estimated as much as 110 m (350 ft) in depth and about 400 m (1,300 ft) wide representing significant hiatus between Permian Kaibab and Triassic Moenkopi Formations. Rocks of Timpoweap and lower red members occupy four paleovalleys in this quadrangle, Quail valley (A on fig. 2), Maple valley (B on fig. 2; Billingsley, 1990a), and two smaller, unnamed paleovalleys, central part of quadrangle (C and D, fig. 2). Small paleovalley at C (fig. 2) is filled with red sandstone, siltstone, and gray conglomerate. Small paleovalley at D (fig. 2) includes basal conglomerate about 9 m (30 ft) thick, overlain by thick beds of red, gypsiferous siltstone. Imbrication of pebbles in all paleovalleys show an east paleoflow of depositing streams. Thickness as much as 75 m (250 ft)

Kaibab Formation (Lower Permian)--Includes, in descending order, Harrisburg and Fossil Mountain Members as defined by Sorauf and Billingsley (1991)

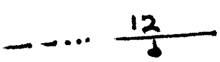
Pkh **Harrisburg Member**--Upper part consists of slope forming, red and gray, interbedded gypsifereous siltstone, sandstone, gypsum, and thin-bedded, gray limestone; mostly eroded away except west-central area of quadrangle. A resistant, pale-yellow or light-gray, fossiliferous, sandy limestone bed, averaging about 1 m (3 ft) thick forms a caprock ledge at top. Middle part is cliff forming marker beds consisting of lower, light-gray, thin-bedded, sandy limestone, and upper, gray, thin-bedded, cherty limestone; chert weathers dark brown or black and often forms the surface bedrock of south part of quadrangle, locally missing in north part. Lower part consists of slope-forming, light-gray, fine- to medium-grained, gypsiferous siltstone, sandstone, thin-bedded gray limestone, and gray gypsum. Solution of gypsum has locally distorted limestone beds of middle part causing them to slump or bend into local drainages. Gradational and arbitrary contact between siltstone slope of Harrisburg Member and limestone cliff of Fossil Mountain Member. Forms slope with middle limestone cliff. Thickness as much as 110 m (350 ft)

Pkf **Fossil Mountain Member**--Light-gray, fine- to medium-grained, thin-bedded, fossiliferous, sandy, cherty limestone. Chert weathers black. Unconformable contact with Toroweap Formation marked by solution and channel erosion with relief as much as 5 m (15 ft); locally obscure due to talus debris. Forms cliff. Thickness about 110 m (350 ft)

Toroweap Formation (Lower Permian)--Includes, in descending order, Woods Ranch, Brady Canyon, and Seligman Members as defined by Sorauf and Billingsley (1991). Only Woods Ranch Member is exposed in this quadrangle

Ptw **Woods Ranch Member**--Gray, gypsiferous siltstone and pale-red silty sandstone with interbedded medium-bedded white gypsum. Only top part exposed in Dutchman Draw near Dutchman Draw fault. Beds are locally distorted due to solution of gypsum. Map contact generalized because of extensive talus cover. Thickness about 12 m (40 ft)


Contact--Dashed where approximately located

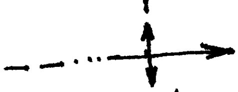


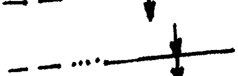
Fault--Dashed where approximately located, short dashed where inferred, dotted where concealed; bar and ball on downthrown side. Number is estimated displacement in meters

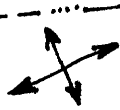

Landslide detachment--Headwall scarp of landslide

Folds--Showing trace of axial plane and direction of plunge; dashed where approximately located; dotted where concealed

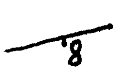

Syncline


Anticline

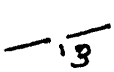

Monocline


Dome

Strike and dip of strata



Inclined



Approximate--Estimated photogeologically


Implied--Determined photogeologically, no estimate of amount of dip determined


Strike and dip of near-vertical joints--Determined photogeologically

●c **Collapse structure**--Circular collapses, strata dipping inward toward central point. May reflect deep-seated breccia pipe collapse originating in Redwall Limestone. Structures in north half of quadrangle are probably local gypsum collapse with little or no dipping strata

→ **Flow direction of basalt**

REFERENCES CITED

Billingsley, G.H., 1990a, Geologic map of the Lizard Point quadrangle, northern Mohave County, Arizona: U.S. Geological Survey Open-File Report 90-643, scale 1:24,000.

-----, 1990b, Geologic map of the Wolf Hole Mountain East quadrangle, northern Mohave County, Arizona: U.S. Geological Survey Open-File Report 90-644, scale 1:24,000.

Billingsley, G.H., 1991, Geologic map of Wolf Hole Mountain and vicinity, Mohave County, northwestern Arizona: U.S. Geological Survey Miscellaneous Investigation Map I-2296, scale 1:31,680.

Huntoon, P. W., 1989, Phanerozoic tectonism, Grand Canyon, Arizona, in Elston, D.P., Billingsley, G.H., and Young, R.A., eds., Geology of Grand Canyon, northern Arizona (with Colorado River guides): 28th International Geological Congress Field Trip Guidebook T115/315, American Geophysical Union, Washington D.C., p. 76-89.

Petersen, S.M., 1983, Geologic map of the Washington fault zone northern Mohave County, Arizona, in Hamblin, W.K., ed., Brigham Young Studies, v. 30, pt. 1, p. 83-94.

Pomeroy, J.S., 1959, Photogeologic map of the Hurricane Cliffs-2 NW quadrangle, Mohave County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-293, scale 1:24,000.

Reynolds, S.J. Florence, F.P., Welty, J.W., Roddy, M.S., Currier, D.A., Anderson, A.V., and Keith, S.B., 1986, Compilation of radiometric age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, Bulletin 197, 258 p.

Reynolds S.J., 1988, Geologic map of Arizona: Arizona Geological Survey, Tucson, Arizona, Map 26, scale 1:1,000,000.

Sorauf J.E., and Billingsley, G.H., 1991, Members of the Toroweap and Kaibab Formations, Lower Permian, northern Arizona and southwestern Utah: Rocky Mountain Geologists, v. 28, no. 1, p. 9-24.

Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region, with a section on sedimentary petrology: in Cadigan, R.A., U.S. Geological Survey Professional Paper 691, 195 p.

Wenrich, K.J., 1985, Mineralization of breccia pipes in northern Arizona: Economic Geology, v. 80, no. 6, p. 1722-1735.

Wenrich, K.J., Billingsley, G.H., and Huntoon, P.W., 1986, Breccia pipe and geologic map of the northeastern Hualapai Indian Reservation and vicinity, Arizona: U.S. Geological Survey Open-File Report 86-458-A, scale 1:48,000, includes pamphlet, 26 p.

Wenrich, K.J., and Huntoon, P.W., 1989, Breccia pipes and associated mineralization in the Grand Canyon region, northern Arizona: in Elston, D.P., Billingsley, G.H., and Young, R.A., eds., Geology of Grand Canyon, Northern Arizona (with Colorado River Guides), 28th International Geological Congress Field Trip Guidebook T115/315, American Geophysical Union, Washington, D.C., p. 212-218.

Wenrich, K.J., and Sutphin, H.B., 1989, Lithotectonic setting necessary for formation of a uranium-rich, solution-collapse breccia-pipe province, Grand Canyon region, Arizona: U.S. Geological Survey Open-File Report 89-0173, 33 p.

Wilson, E.D., Moore, R.T., and Cooper, J.R., 1969, Geological map of the State of Arizona: Arizona Bureau of Mines, University of Arizona, scale 1:500,000.

CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS AND IGNEOUS ROCKS

* See description of map units for exact unit age assignment